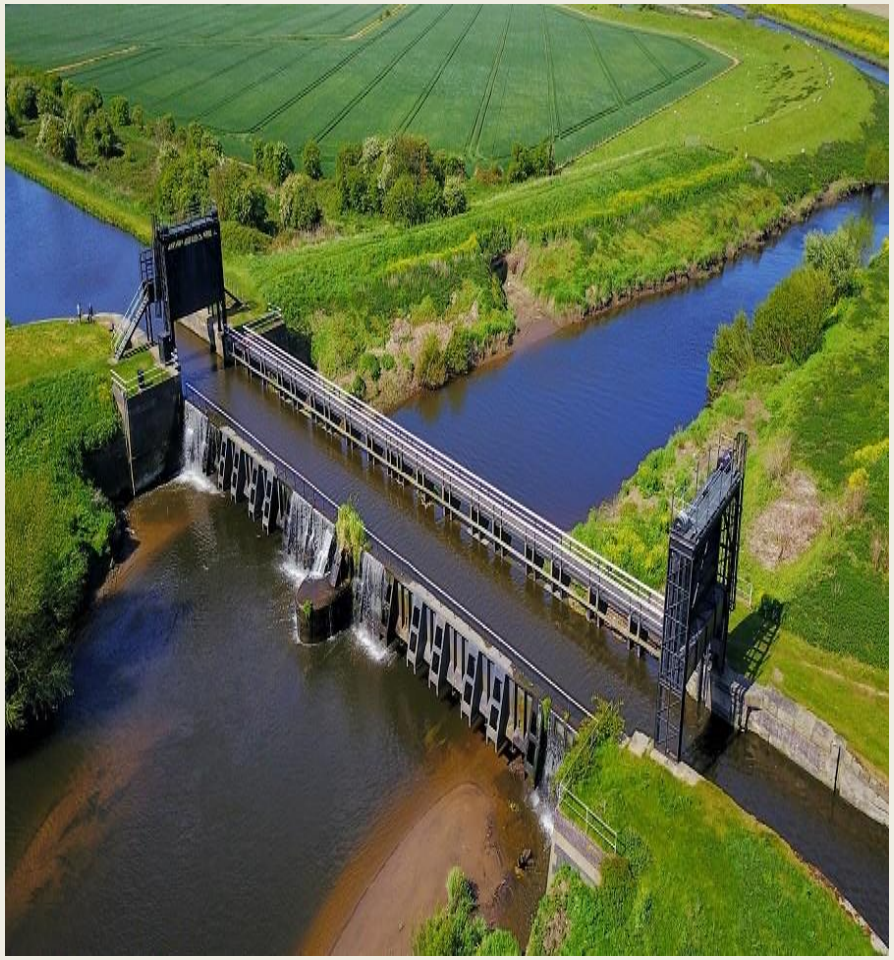
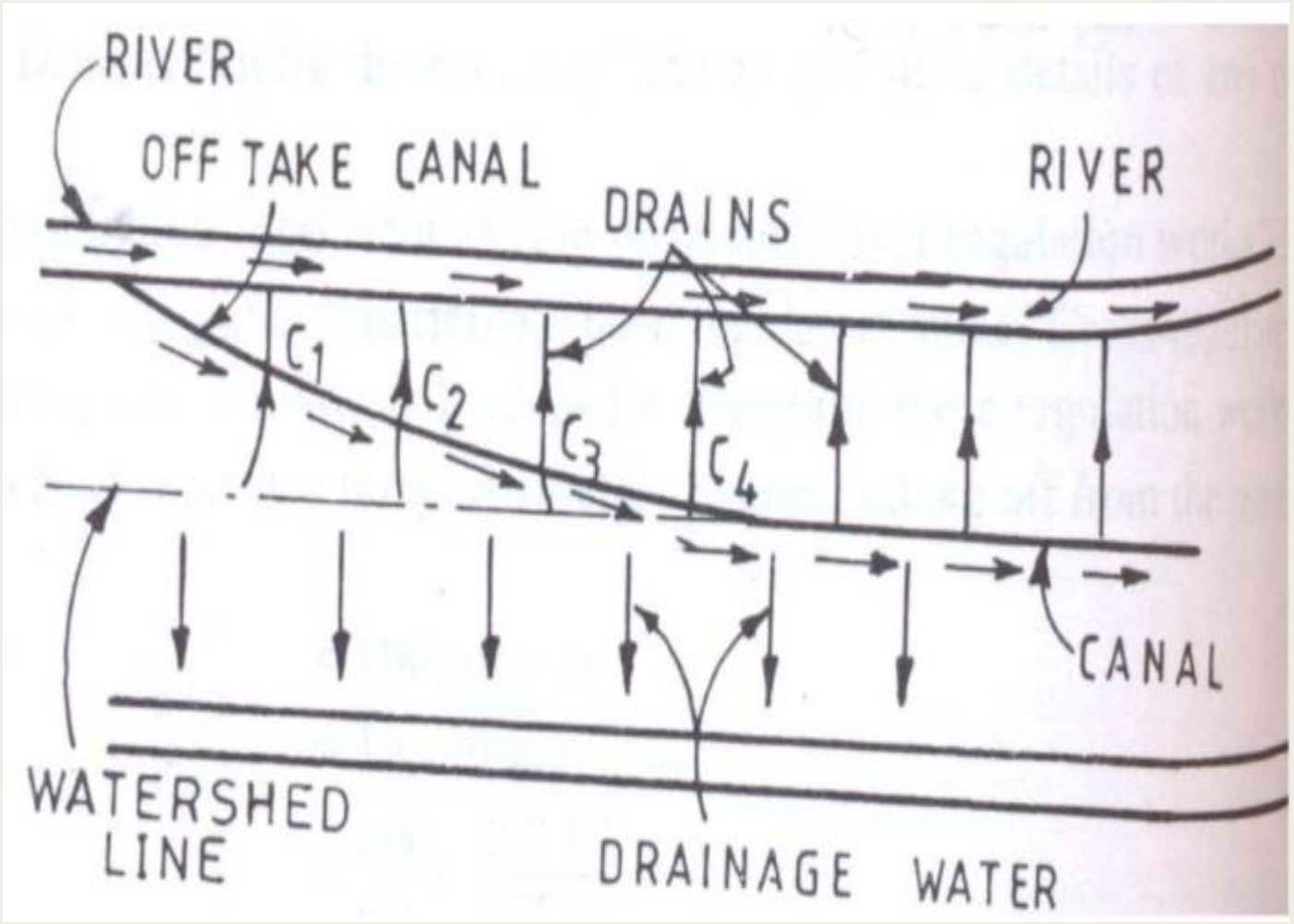
Cross Drainage Structure

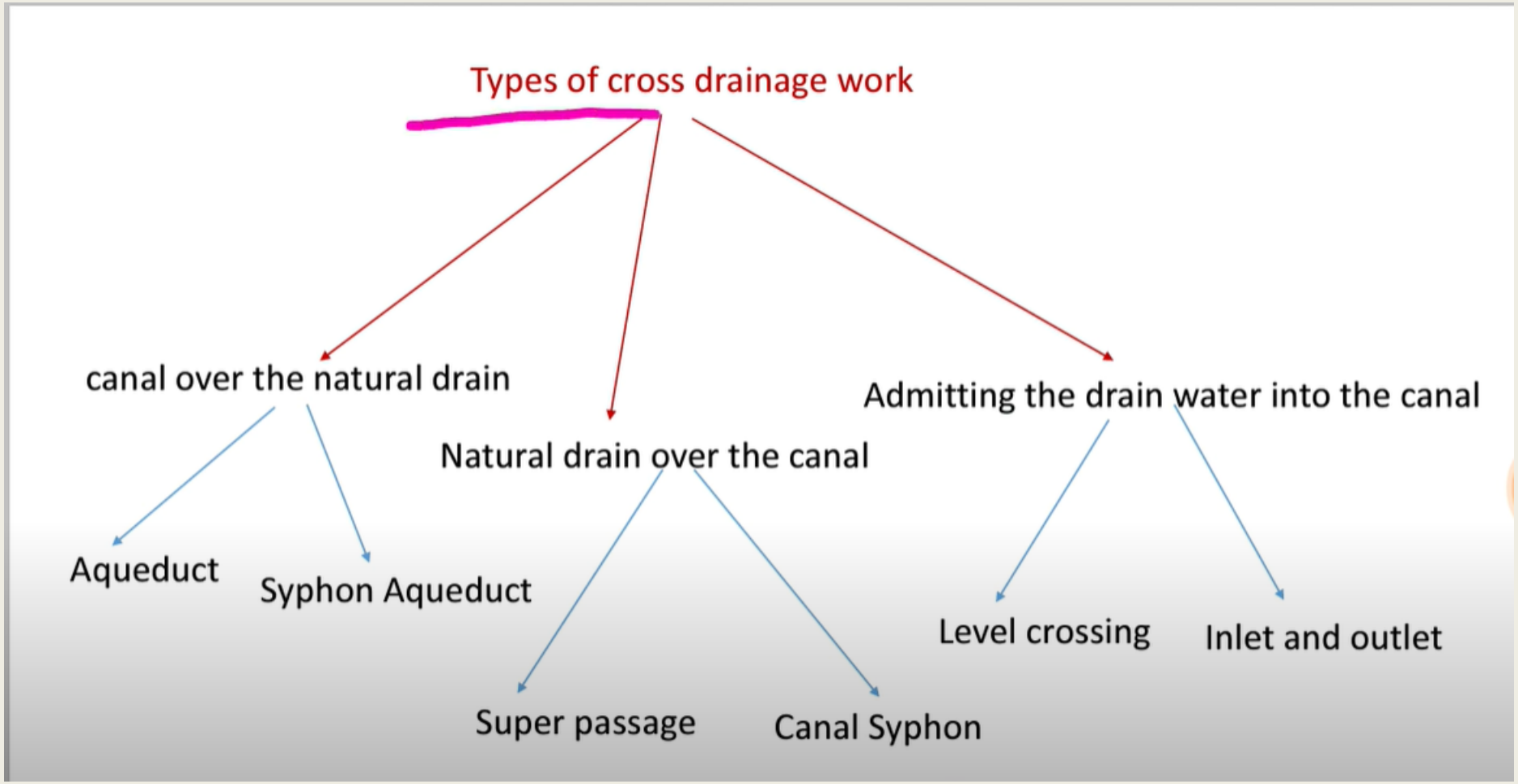




Introduction

- A cross drainage structure is a structure which is constructed at the crossing of a canal and natural drain, so as to dispose the drainage water without interrupting the continuous canal supplies.
- In order to reduce cross drainage works canal is aligned along the ridge line

❖ Types of cross drainage works



❖ Types of cross drainage works

(a) irrigation canal passes over the drainage

(I) Aqueduct

(II) Siphon aqueduct

(b) Drainage passes over the irrigation canal

(I) Super passage

(II) canal siphon

(c) Admitting drain water in canal

(I) Level crossing

(II) Inlet and outlet

(a) irrigation canal passes over the drainage

(I) Aqueduct

- When the H.F.L. of the drain is sufficiently below the bottom of the canal such that drainage water flows freely under gravity is known as aqueduct.
- In this, canal water is carried across drainage in a trough supported on piers..
- Provided when sufficient level difference is available between the canal and natural drain and canal bed is sufficiently higher than H.F.L.

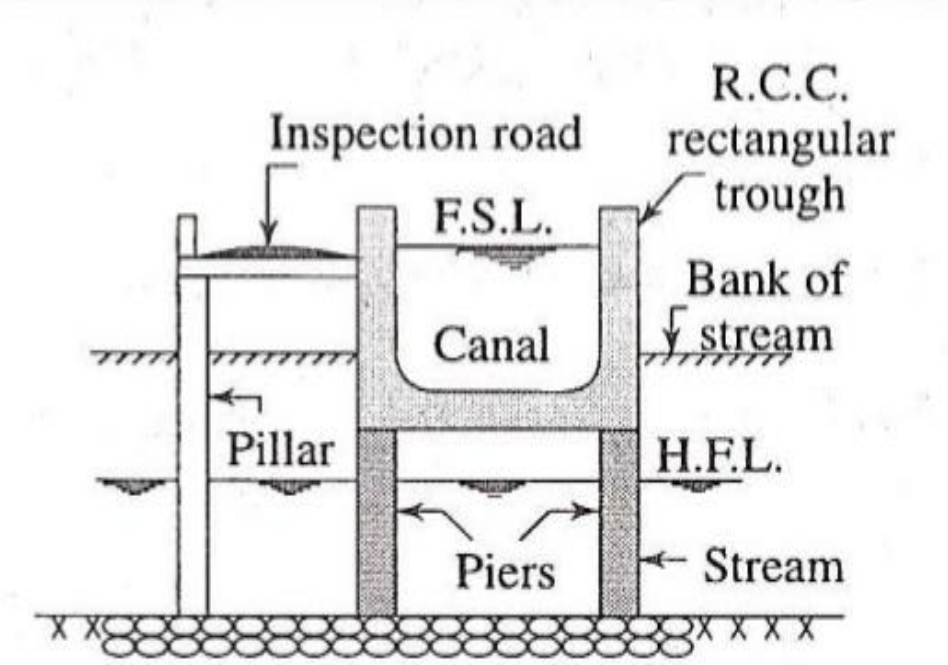
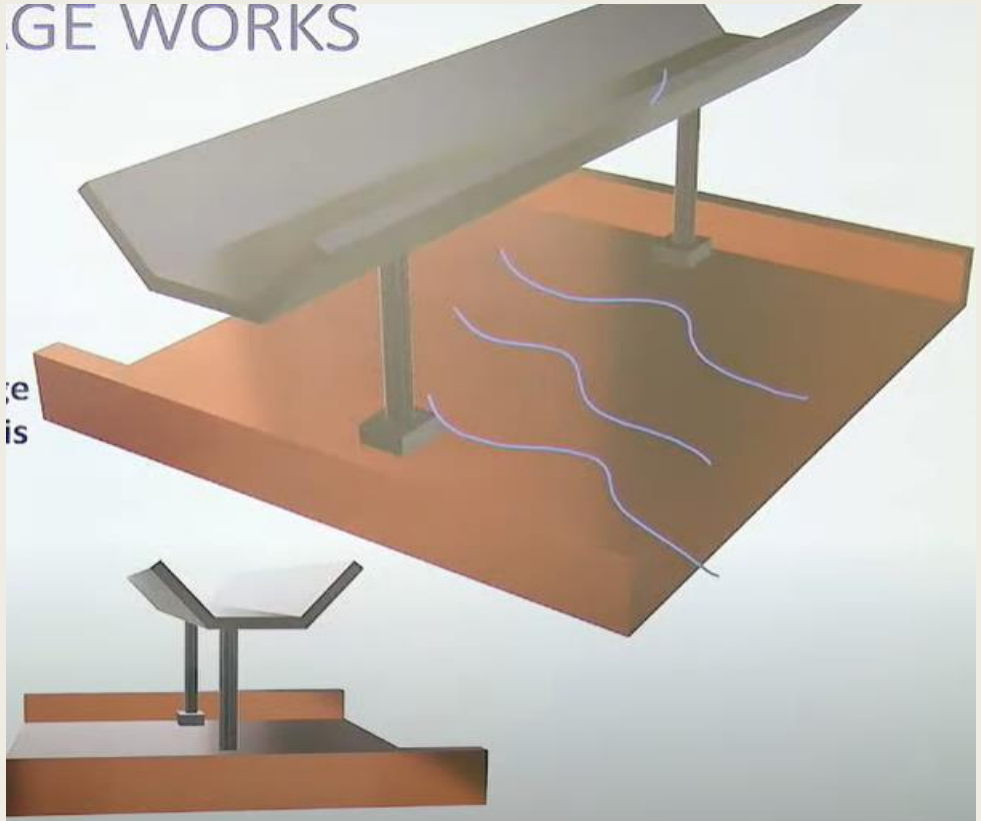


Fig: Aqueduct



Aqueduct

(II) Siphon aqueduct

- Constructed at a place where the HFL of the drain is much higher above the canal bed and water runs under siphonic action through the aqueduct barrel.
- The drain bed is generally depressed and provided with pucca floors, on the upstream side, the drainage bed may be joined to the pucca floor either by a vertical drop or by a glacis of 3:1.
- The downstream rising slope should not be steeper than 5:1

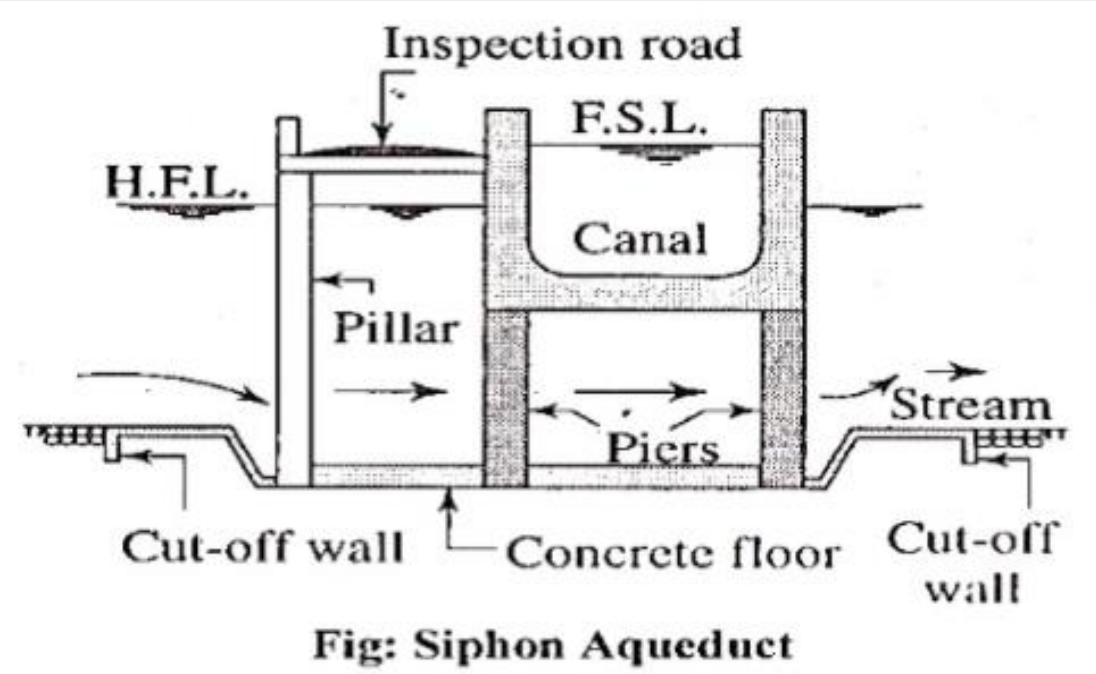
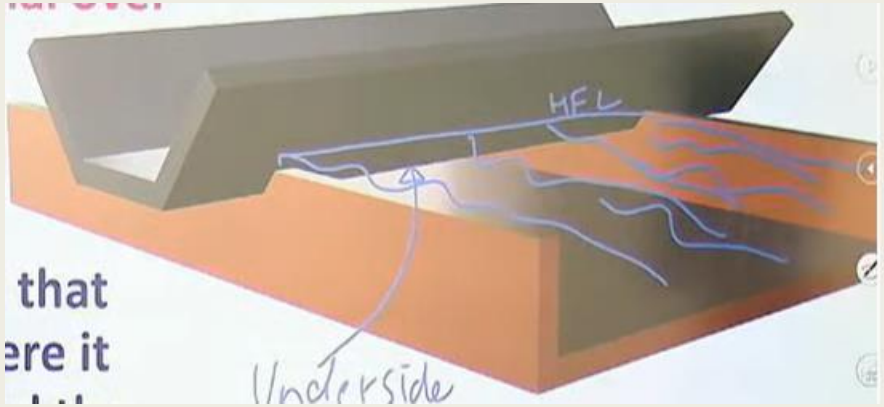
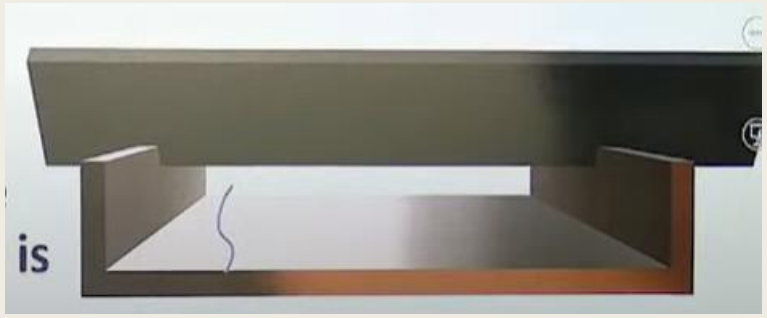


Fig: Siphon Aqueduct





(b) Drainage passes over the irrigation canal

(I) Super passage

- The hydraulic structure in which the drainage is passing over the irrigation canal is known as super passage.
- The structure is suitable when the bed level of drainage is above the flood surface level of the canal.
- A super passage is reverse of an aqueduct.

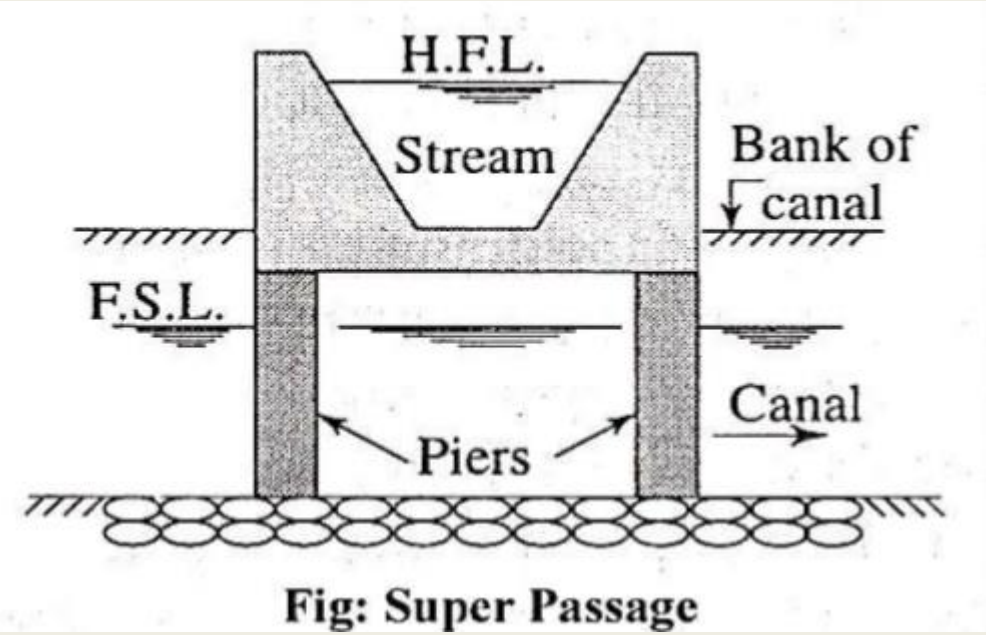


Fig: Super Passage

(II) Siphon super passage (canal siphon)

The hydraulic structure in which the irrigation canal pass below the drainage under siphonic action,

This structure is suitable when the bed level of drainage is below the full supply level of canal.

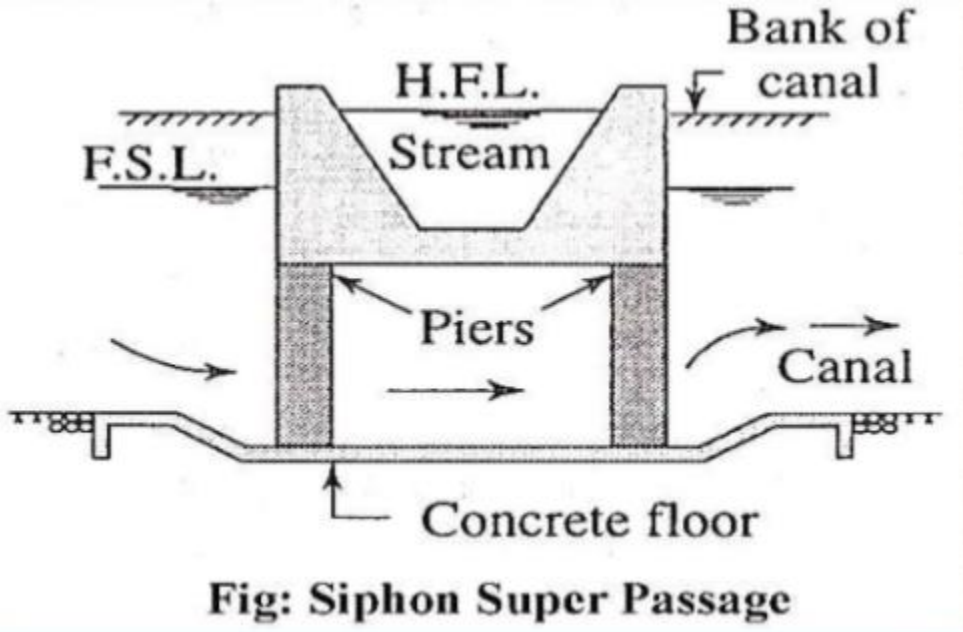
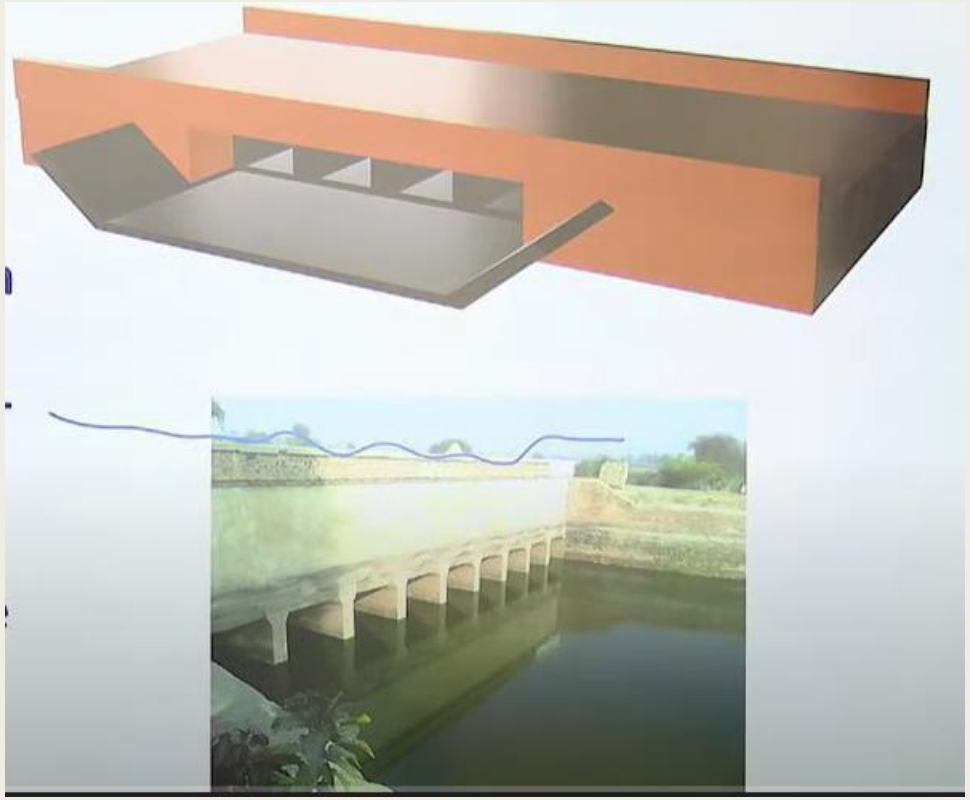
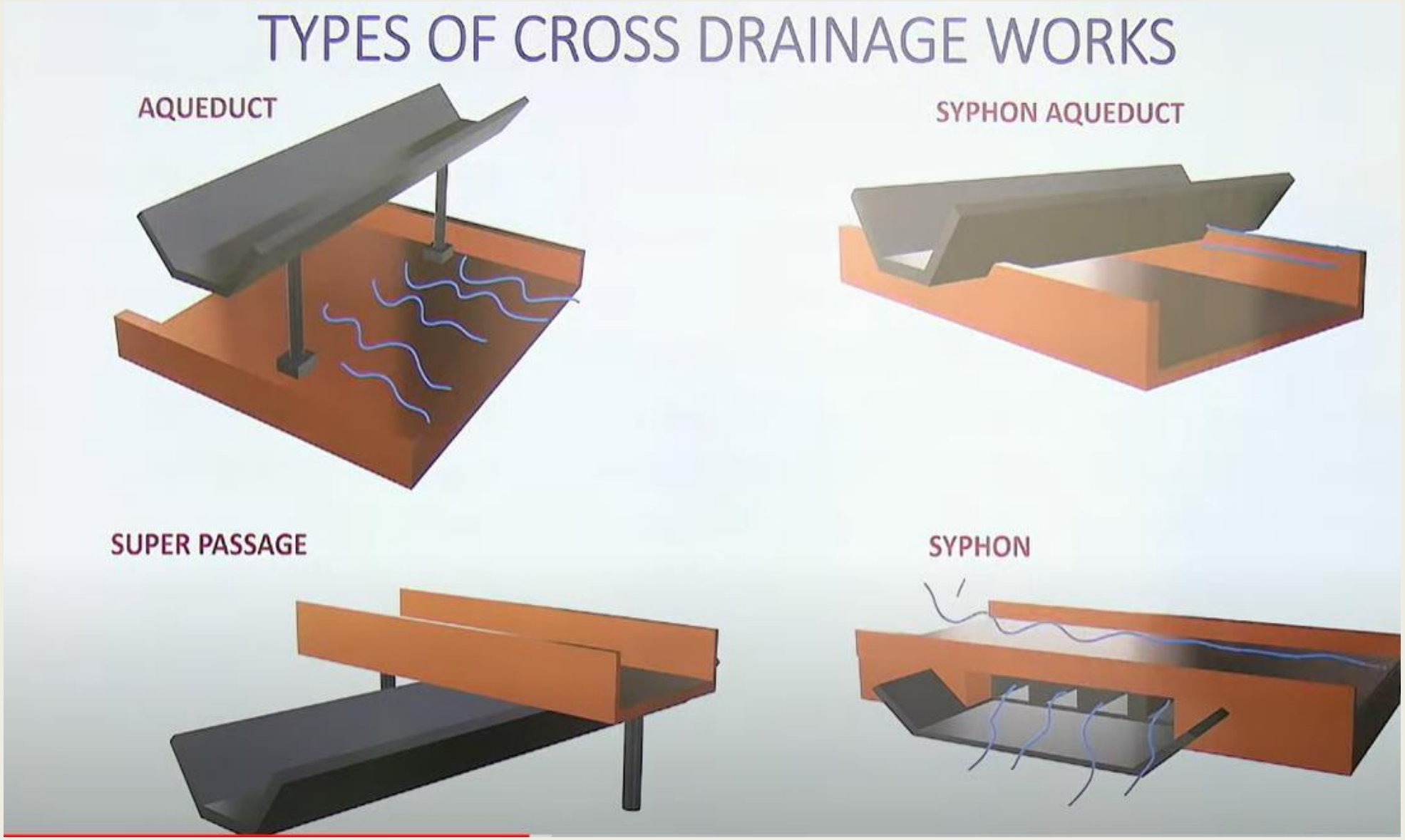


Fig: Siphon Super Passage



TYPES OF CROSS DRAINAGE WORKS



(c) Drainage and canal intersection each other of the same level

In this type the canal water and the drain water are allowed to intermix with each other. It has two types:

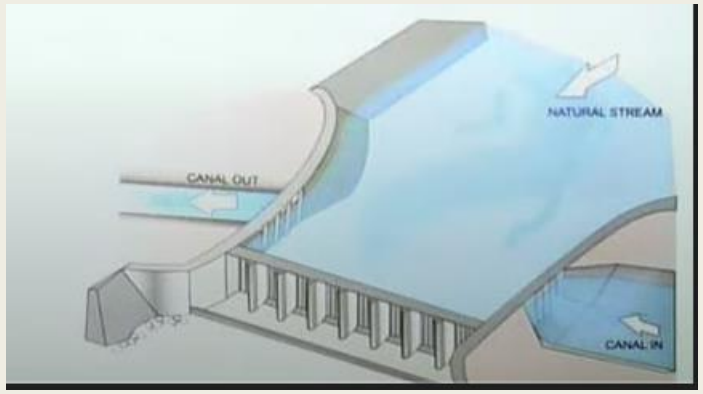
(I) Level crossing

A level crossing is a cross drainage works provided when the natural drain and canal meets each other at approximately same level.

Suitable when sediment concentration of drainage is low.

The level crossing consists of the following components,

- Crest wall
- Drainage regulator
- Canal regulator



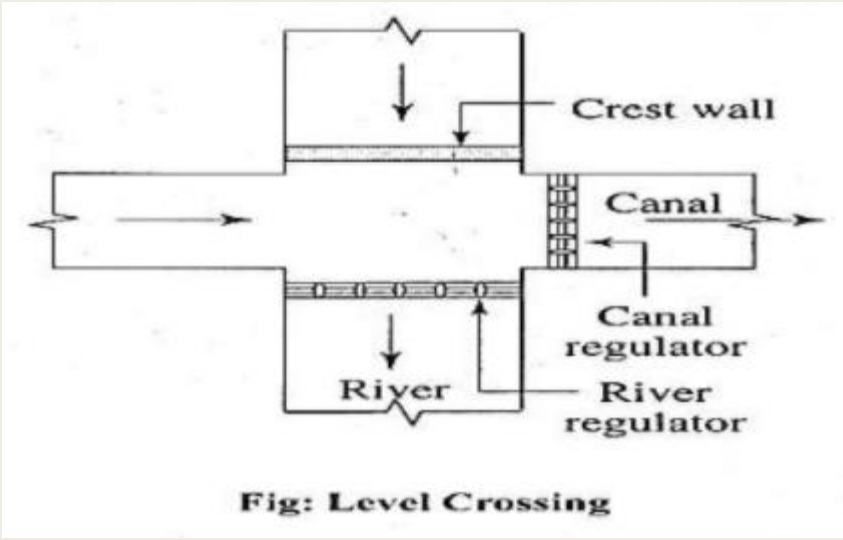


Fig: Level Crossing

(II) Inlet and outlet

Provided when the crossing of small drainage with small channel. No hydraulic structure is constructed. Simple opening are provided for flow of water.

Suitable when sediment concentration of drainage is low.

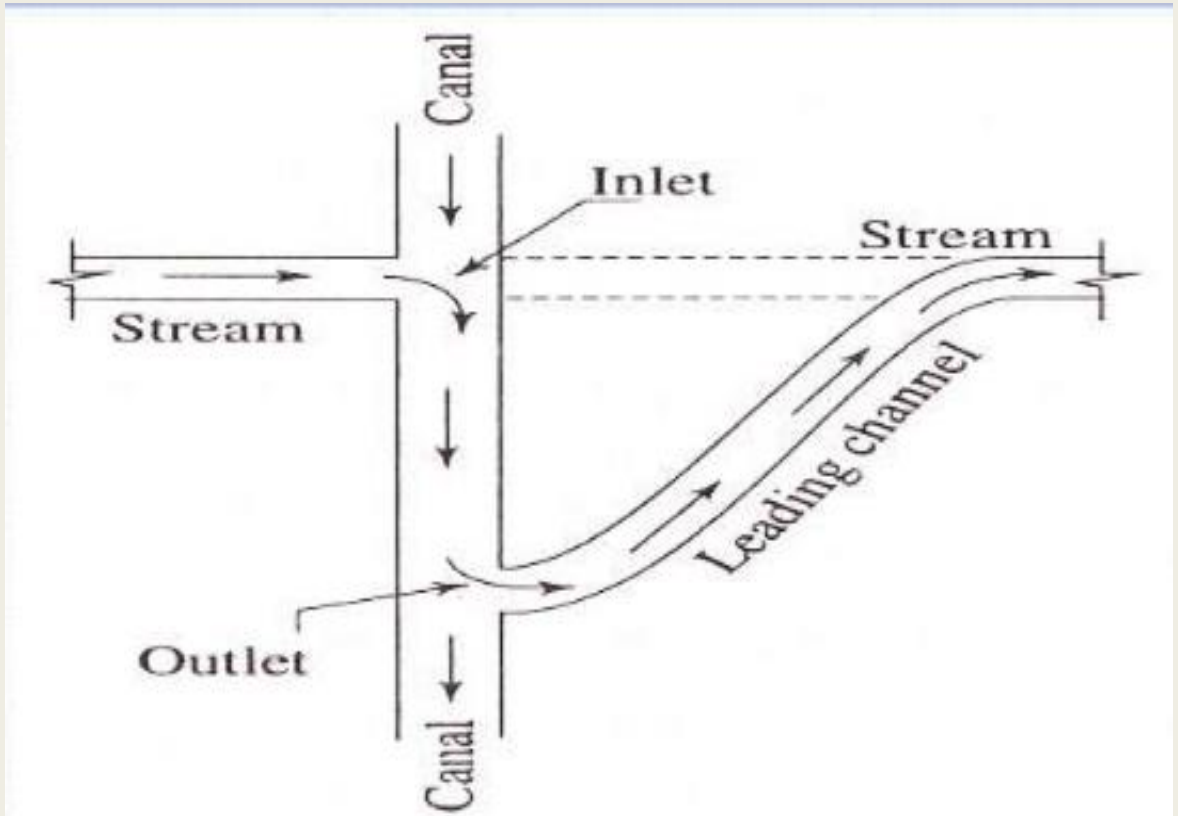


Fig: Inlet and outlet

Q.N Design a siphon aqueduct if the following data at the crossing of canal and drainage are given.

- ✓ Discharge of canal = 50 Cumecs
- ✓ Bed Width of canal = 30 m
- ✓ Full supply depth of canal = 1.5 m
- ✓ Bed level = 106.m
- ✓ Side slope of canal = 1.5 H:1V
- ✓ High Flood discharge of drainage = 500 Cumecs
- ✓ High flood level of drainage = 107 m
- ✓ Bed level of drainage = 104 m
- ✓ General ground level = 106 m

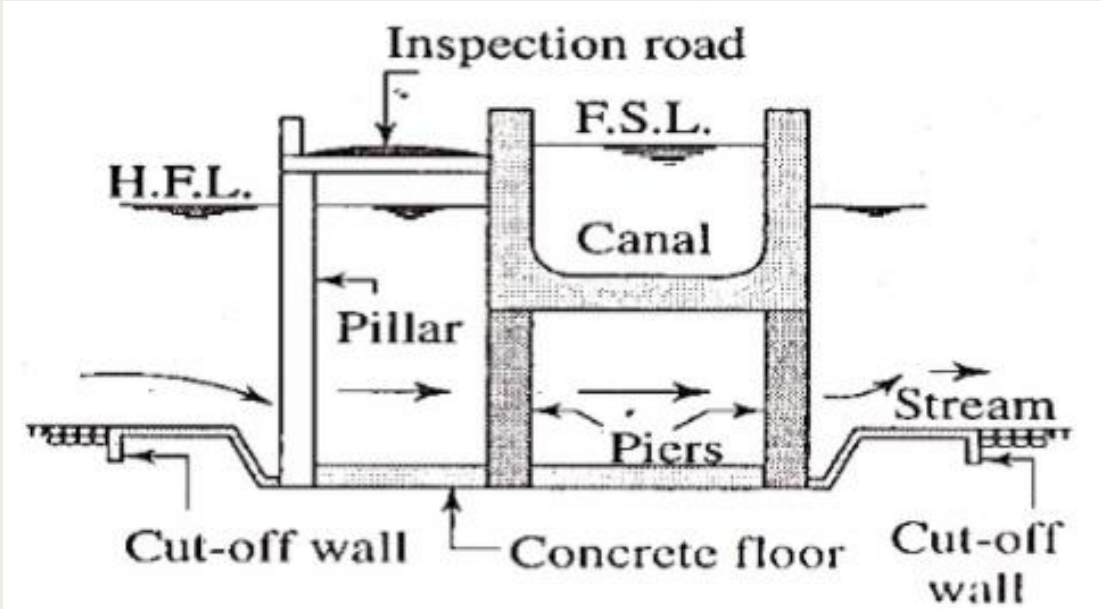


Fig: Siphon Aqueduct

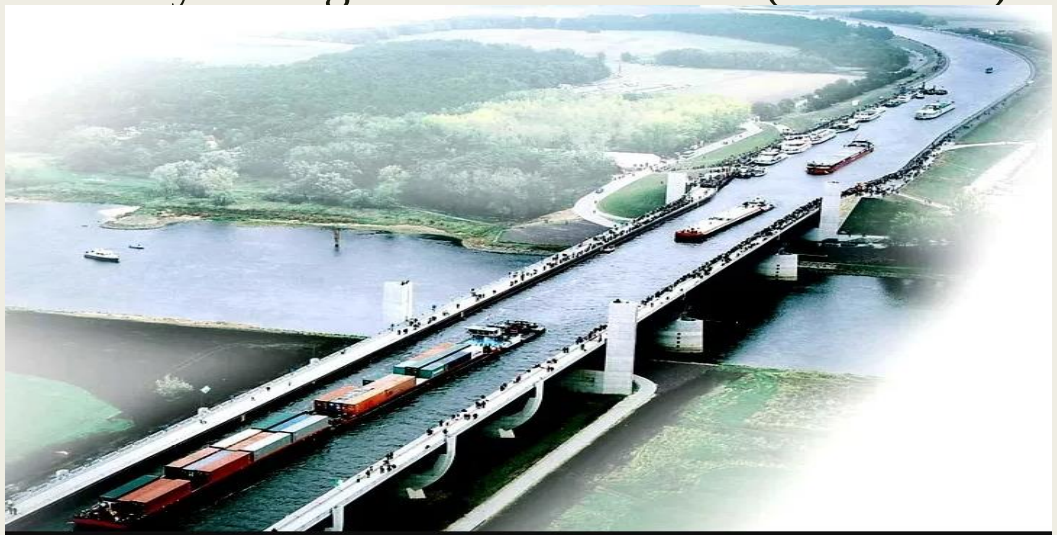
- Bed level of canal is slightly below drainage H.F.L. siphon aqueduct is adopted.

Step 1: Design of drainage waterway

- Lacey's regime perimeter = p = 4.75 √Q = 4.75√500 = 106.21 m
- Provide 12 clear spans of 8 m each and let the width of each pier be 1.5 m
- Length of water way = 12 × 8 +11× 1.5 = 112.5 m
- Let the limiting velocity of through the siphon barrels is 2 m/s.
- Height of barrels required =Discharge / (Velocity x Width of waterway)

  =500/ (2×8×12)

  = 2.6 m
- Hence, providing 12 rectangular barrels 8 m wide and 2.5 m height.
- Actual velocity through the barrels= 500/ (2.5×12×8) = 2.08 m/s



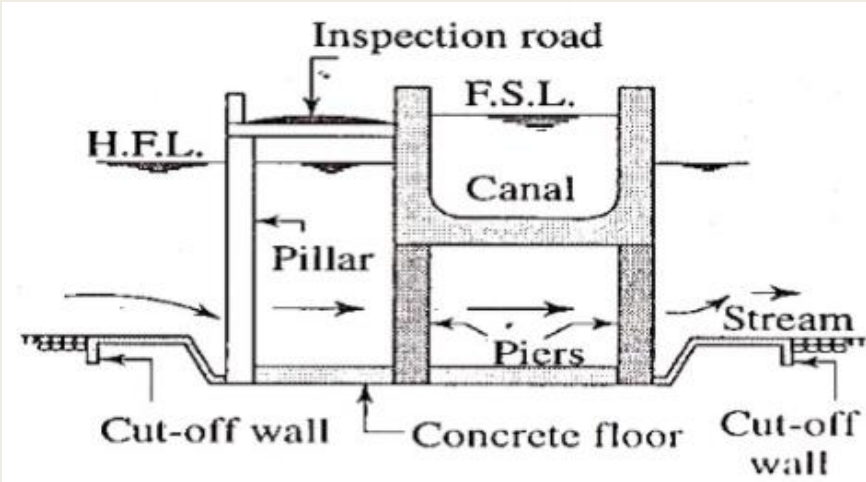


Fig: Siphon Aqueduct

- **Step 2: Design of canal waterway**
- Normal bed width of canal= 30 m
- Let the width be reduced to 15 m.
- Velocity through trough= 50/ (1.5×15) = 2.22 m/s < 3 m/s (OK)
- Providing a splay of 2:1 in contraction,
- Length of contraction transition= (30-15) × 2/2 = 15m
- Providing a splay of 3:1 in expansion,
- Length of expansion transition = (30-15) *3 /2=22.5m
- Length of flumed rectangular portion of the canal between abutments= 112.25 m (provided).
- In transitions, the side slopes of the canal section shall be warped in plan from the original slope of 1.5 H: 1 V to vertical.

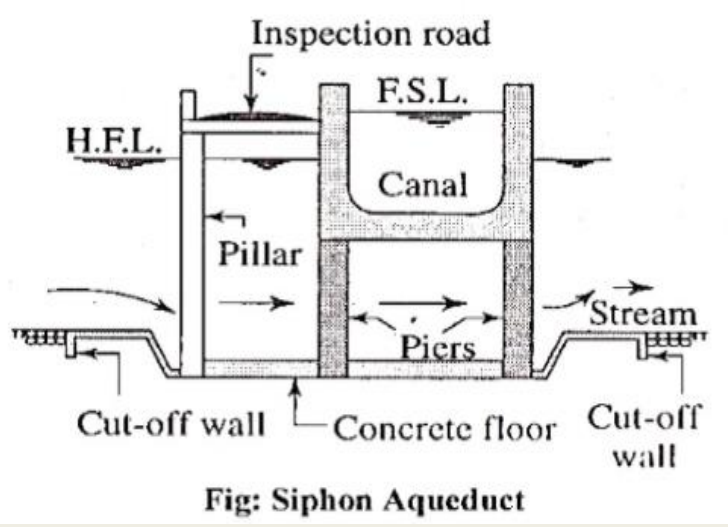
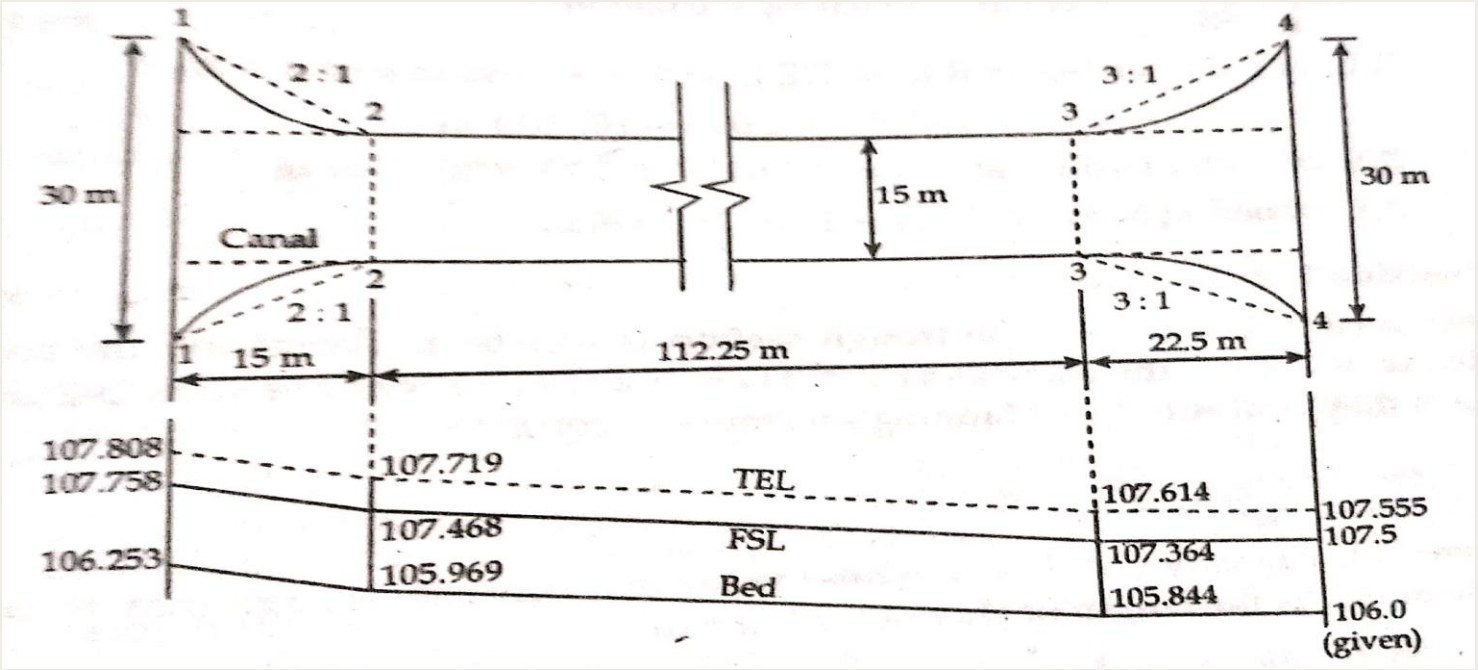
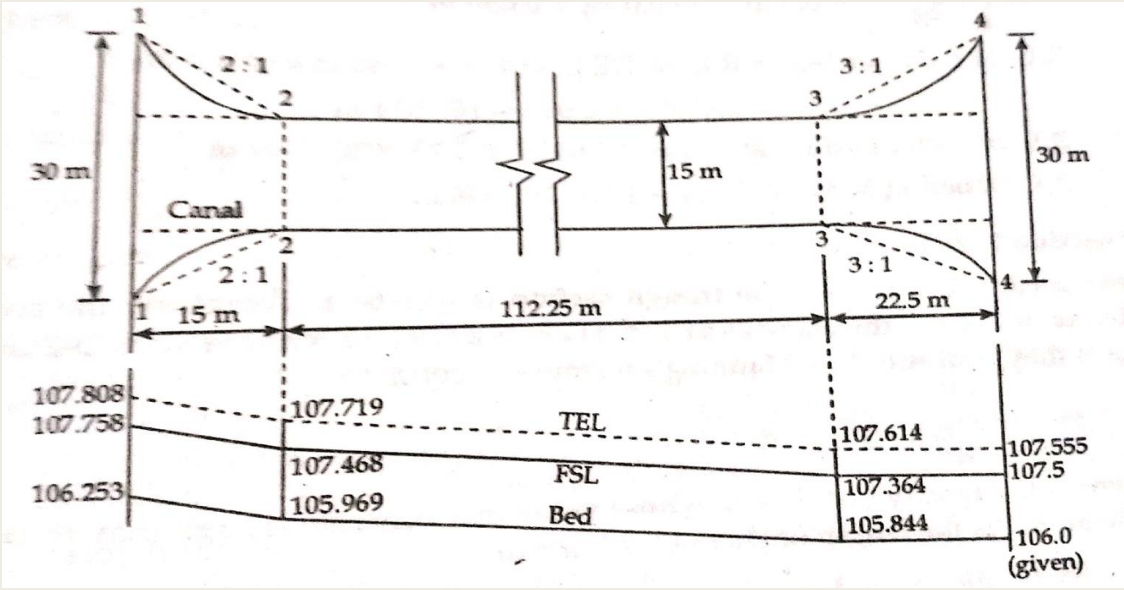


Fig: Siphon Aqueduct

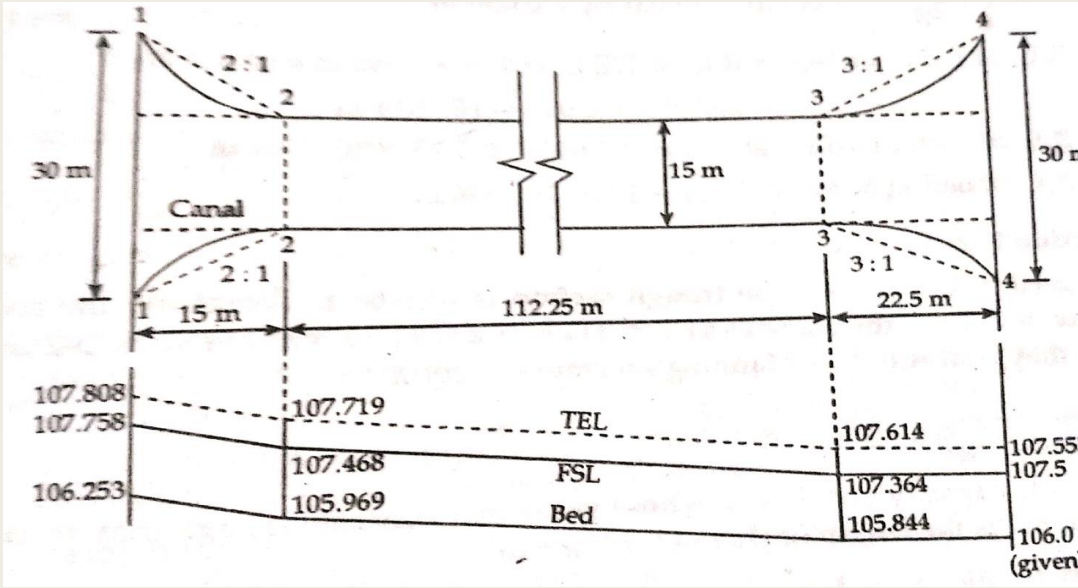


- **Step 3: Design of bed level at different sections**
- **At section 4-4**
- When canal returns to its normal sections we have known conditions as follows.
- Area of trapezoidal section= (B+1.5 y) y
- (30+ 1.5 x 1.5)×1.5= 48.37 m^2
- Where, B = bed width=30 m
- Y = depth = 1.5 m
- Velocity of V_4 = Q/A= 50/ 48.37= 1.03 m/sec.
- Velocity of head = $V_4^2/2g$ = $1.03^2/2g$= 0.055 m
-
- RL of canal bed at 4-4 =106 m (given)
- Water depth = 1.5m (given)
- RL of water surface at 4-4 = 106 +1.5 = 107.5 m
- RL TEL at 4-4 = 107.5 +0.055= 107.555 m



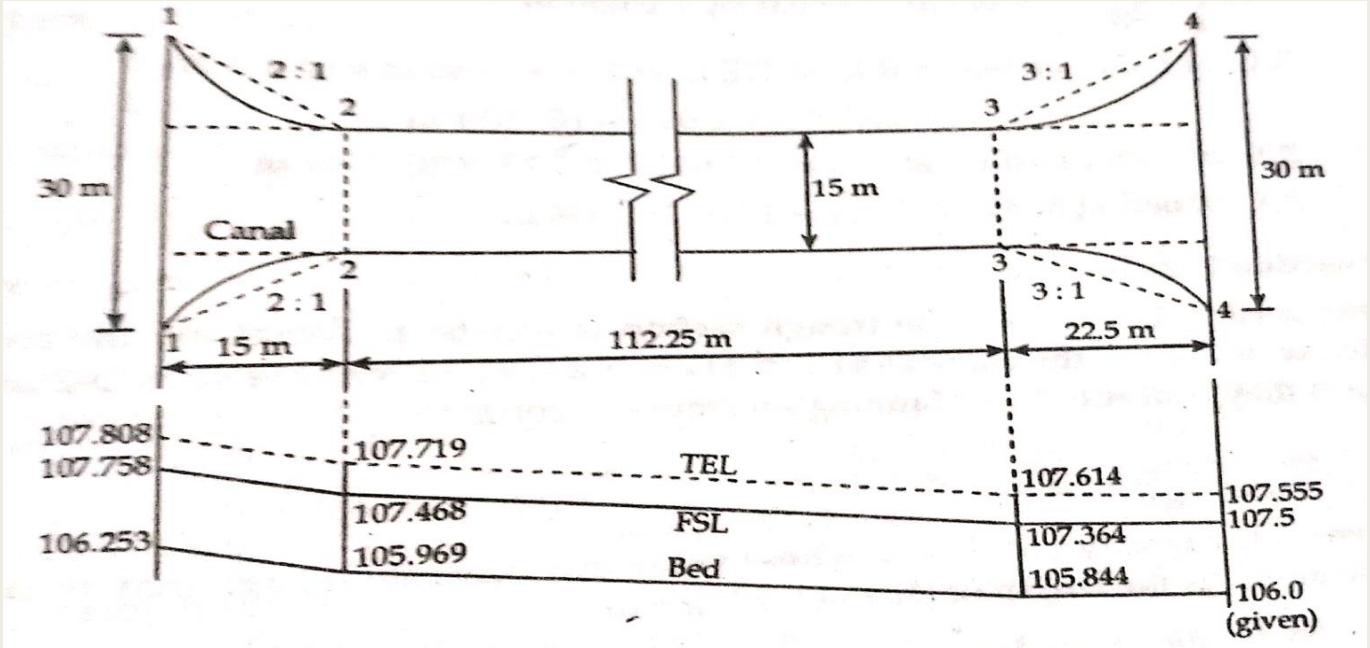
- **At section 3-3**
- Assuming the constant depth of 1.5 m throughout the channel,
- We have at section 3-3, a rectangular channel, as follows:
- Bed Width = 15 m
- Depth = 1.5 m (assumed constant)
- Area = 15 x 1.5 = 22.5m^2
- Velocity =V_3= 50/22.5 = 2.22 m/sec.
- Velocity head = $V_3^2/2g$= $(2.22)^2/2g$ = 0.25 m
- Assuming that the loss of head in expansion from section 3-3 to section 4-4 is taken as;

- $=0.3[(V_3^2-V_4^2)/2g] = 0.059$ m
- R.L. of T.E.L. at 3-3 = R.L. of T.E.L. at 4-4 + Loss in expansion
- = 107.555 +0.059 = 107.614 m
- R.L. of water surface at 3-3 = 107.614 -0.25 =107.364 m
- R.L. of bed at 3-3 = 107.364-1.5 = 105.864 m
-
- **<u>At section 2-2</u>**
- From section 2-2 to 3-3, the trough section is constant.
- Therefore, the area and velocity at 2-2 are the same as at 3-3.
- There is a friction loss between 2-2 and 3-3 which may computed by Manning's formula as equal to;
- $H_L = (n^2V^2L)/R^{4/3}$
- Where, n is rugosity coefficient, whose value in a concrete trough may be taken 0.016 and L is the length of channel = 112.5 m.
- Hydraulic mean depth (R) = A/P = (15×1.5)/ (15+2×1.5)
- = 22.5/18= 1.25 m
- Velocity in trough (V) = Q/A= 50/22.5
- = 2.22 m/s
- Head loss (H) = $(n^2V^2L)/R^{4/3}$
- =0.105 m
- R.L. of T.E.L. at 2-2 =R.L. of TEL. at 3-3 + Head loss in trough
- = 107.614 +0.105
- = 107.719 m
- RL of water level at 2-2 = 107.719 - velocity head
- = 107.719 -0.25 = 107.469 m
-
- R.L. of bed at 2-2 = 107.469 -1.5 = 105.969 m
-



At section 1-1

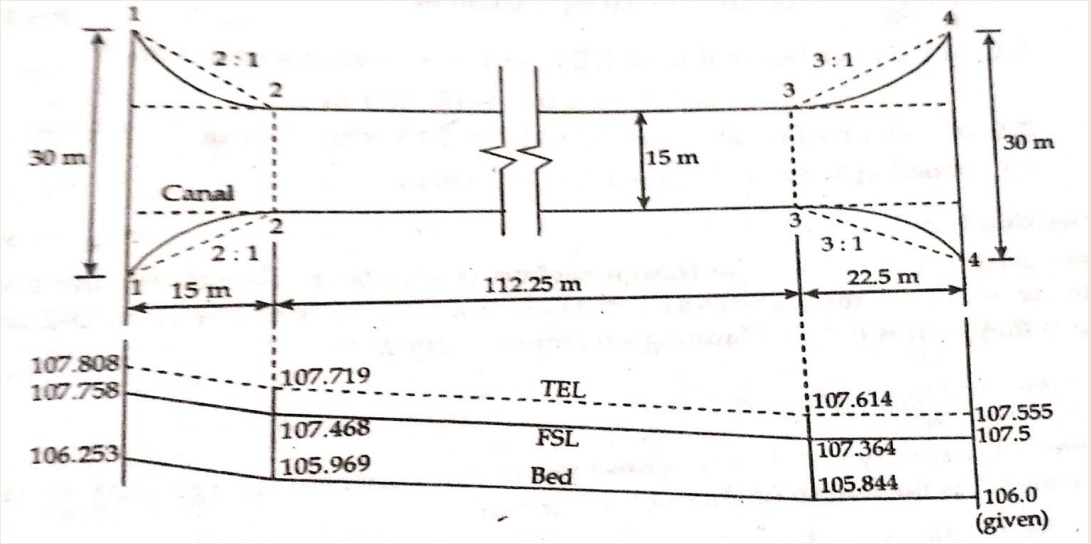
- Loss of head in contraction transition from section 1-1 to section 2-2 may be taken as;
- $= 0.2[(V_2^2-V_1^2)/2g]$
- $= 0.039$ m
- R.L. of T.E.L. at 1-1 = R.L. of T.E.L. at 2-2 + Loss in contraction
- = 107.719 +0.039
- = 107.758 m
- RL of water level at 1-1 = 107.758 -0.055
- = 107.703 m
- RL of bed at 1-1 required to maintain constant depth = 107.703 - 1.5
- = 106.203 m
- All these levels are plotted and shown in above figure.



- **Step 4: Design of transition**

i) Contraction transitions

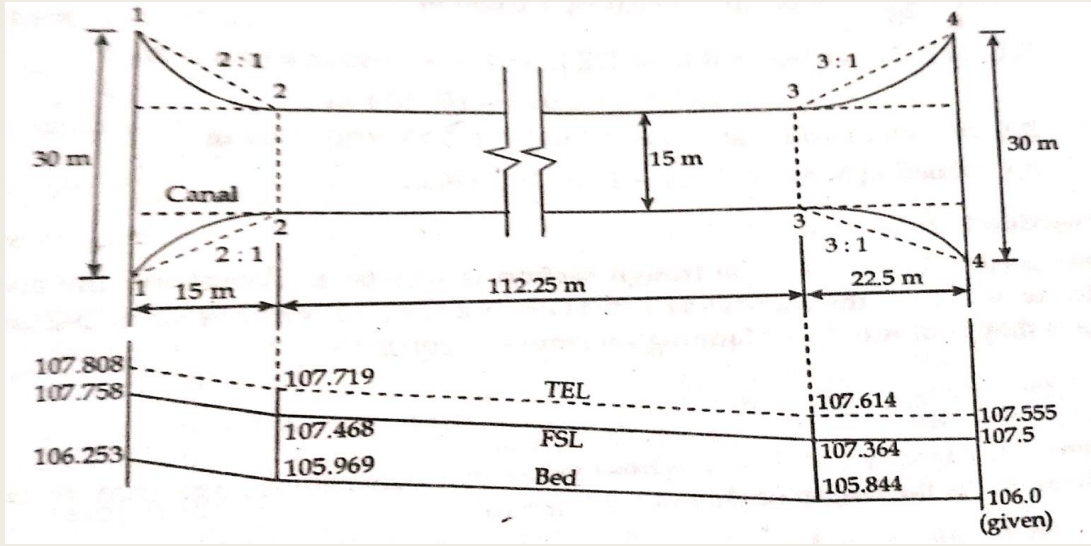
Since depth is constant, the transition shall be designed on the basis of **Mitra's** hyperbolic transition equation given by;



- $B_x = (B_n \times B_f \times L_f) / [B_n \times L_f - x (B_n - B_f)]$
- Where, B_f = 15 m
- B_n = 30 m
- L_f = 15 m
- Substituting the above values; we get
- $B_x = 6750 / (450 - 15x) = 450 / (30 - x)$
-
- For various values of x lying between o to 15 m, various values of B, are worked out as shown in table
- The distance 'x' is measured form the flumed section 2-2

X	0	2	4	6	8	10	12	14	15
Bx	15	16.07	17.30	18.75	20.45	22.5	25	28.12	30

- **Expansion transition**
- In this case, we have,
- B_f = 15 m
- B_n = 30 m
- L_f = 22.5 m
- Using these values, we get
- $\mathbf{B_x = (B_n \times B_f \times L_f) / [B_n \times L_f - x (B_n - B_f)]}$
- $B_x = 675 / (45-X)$



- For various values of x lying between 0 to 22.5 m,
- Corresponding values of B_x are worked out as shown in the table.
- The distance 'x' is measured from the flumed section 3-3.

X	0	2	4	6	8	10	12	14	16	18	20	22.5
Bx	15.0	15.7	16.46	17.3	18.25	19.3	20.4	21.75	23.3	25	27	30

❖ Selection of type of cross drainage works

The factors which affect the selection of suitable type of cross drainage works are:

1. Relative bed levels.
2. Discharge of drainage
3. Availability of suitable foundation.
4. Economic consideration.
5. Construction problems.
6. Suitable canal alignment.

- The following considerations are important
- When the bed level of the canal is much above the HFL of the drainage, an aqueduct is the obvious choice.
- When the bed level of the drain is well above FSL of canal, super passage is provided.
- The necessary headway between the canal bed level and the drainage HFL can be increased by shifting the crossing to the downstream of drainage. If, however, it is not possible to change the canal alignment, a siphon aqueduct may be provided.
- When canal bed level is much lower, but the FSL of canal is higher than the bed level of drainage, a canal siphon is preferred.
- When the drainage and canal cross each other practically at same level, a level crossing may be preferred. This type of work is avoided as far as possible.

Q:1) Design a suitable cross-drainage work, given the following data at the crossing of a canal and drainage.

Canal

Full supply discharge = 32 cumecs
FSL = 213.5 m
CBL = 212 m
Canal bed width = 20 m
Trapezoidal canal section = 1.5 H : 1 V
Canal water depth = 1.5 m

Drainage

High Flood discharge = 300 cum
HFL = 210 m
High flood depth = 2.5 m
General GL = 212.5 m

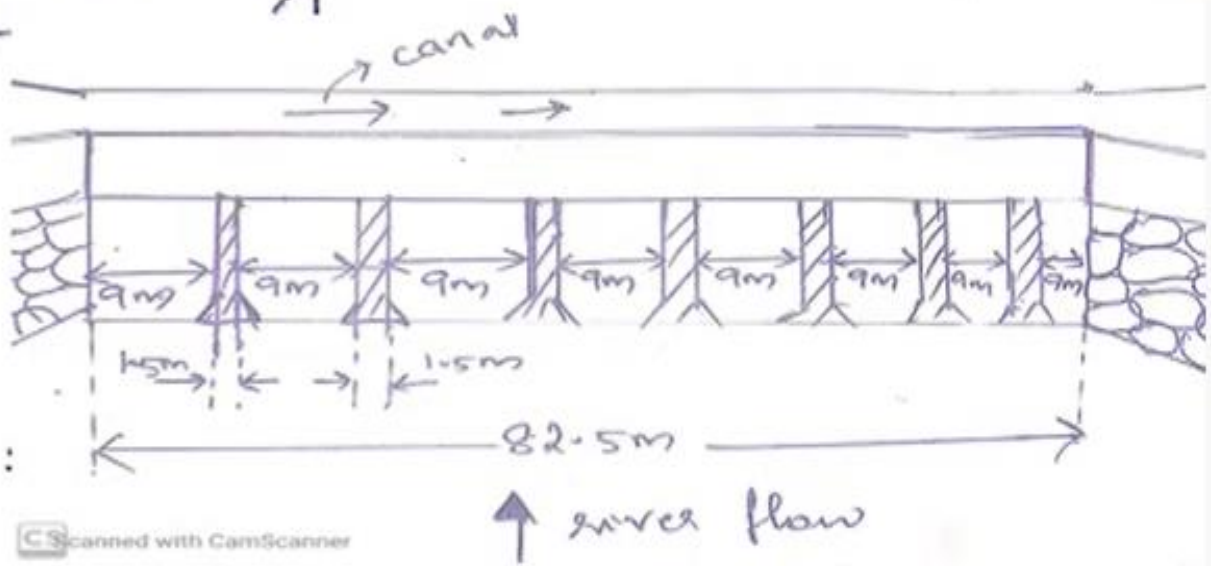
Step 1: Identification of CDW

$Q_D = 300$ Cumecs
$Q_C = 32$ cumecs
$\Rightarrow Q_D > Q_C$

CBL = 212 m
DBL = 210 − 2.5 = 207.5 m
$\Rightarrow$ CBL > DBL

HFL = 210 m $\Rightarrow$ CBL > HFL $\therefore$ Aqueduct

Step 2: Design of drainage waterway



a) Length of waterway

$$P = 4.75\sqrt{Q}$$

$$= 4.75 \times \sqrt{300}$$

$$= 82.27 \sim = 82.3\text{m}$$

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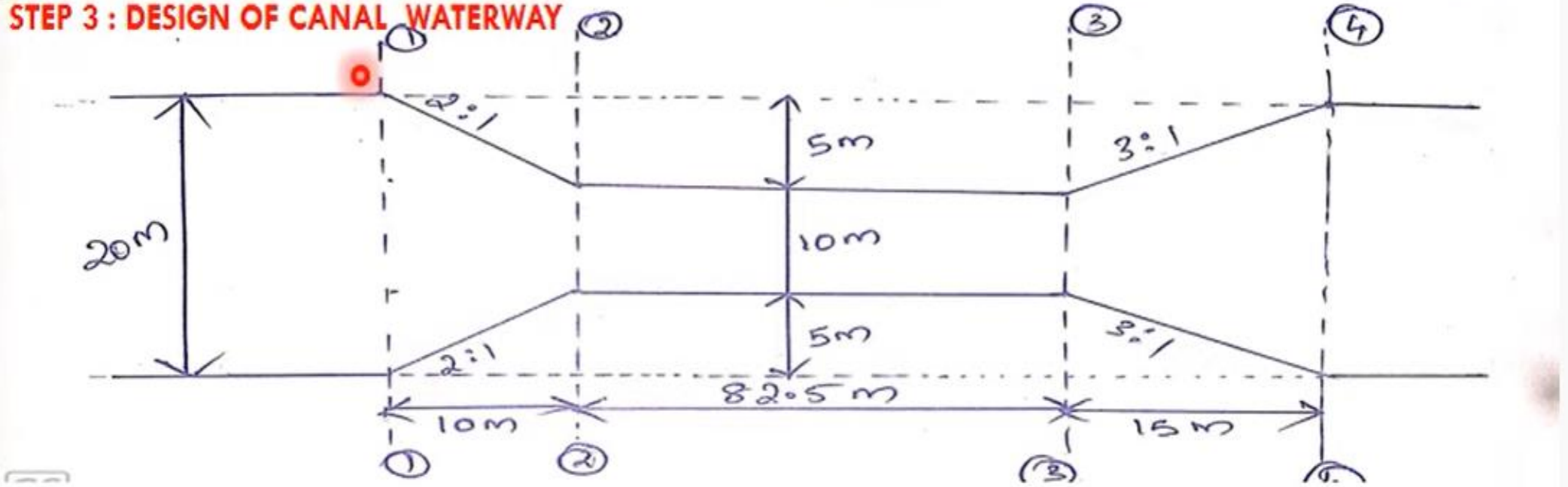
b) Assuming clear span = 9m & pier thickness = 1.5 m

$$\text{no: of bays} = \frac{82.3}{9+1.5} = 7.84 \approx 8$$

$$\text{no: of piers} = 8 - 1 = 7$$

W_A, Actual width of drainage way $= 8 \times 9 + 7 \times 1.5 = 82.5\text{m}$

STEP 3 : DESIGN OF CANAL WATERWAY



Normal bed width of canal = 20 m (given)

Let the width be reduced to 10 m

$$B_f = \frac{B}{2} = 10 \text{ m}$$

Providing a splay of 2:1 in contraction,

Length of contraction transition = $2 \times \frac{(20-10)}{2} = \underline{10 \text{ m}}$

III^{by} providing a splay of 3:1 in expansion,

Length of expansion transition = $3 \times \frac{(20-10)}{2} = \underline{15 \text{ m}}$

The length of flumed rectangular portion of canal b/w abutments = $\underline{82.5 \text{ m}}$.

Step 4: Design of transitions

Mitra's Hyperbolic Equation

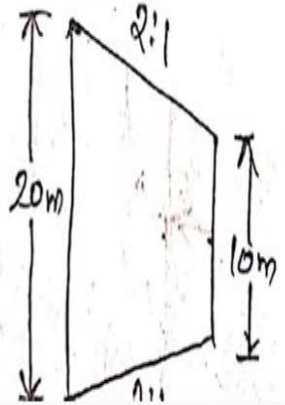
$$B_x = \frac{B_n B_f L}{B_n L - (B_n - B_f)x}$$

a) For contraction transitions

$B_n = 20\ m$

$B_f = 10\ m$

$L = 10\ m$



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$$B_x = \frac{20 \times 10 \times 10}{20 \times 10 - x(20-10)}$$

$$= \frac{200}{20 - x}$$

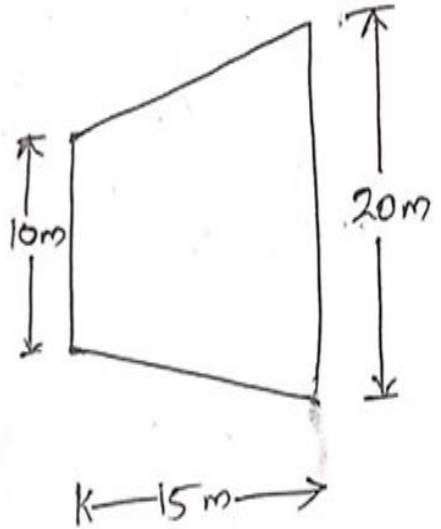
x	0	2	4	6	8
B_x	10	11.11	12.5	14.28	16.67

b) For expansion transitions

$B_n = 20\ m$

$B_f = 10\ m$

$L = 15\ m$



$$B_x = \frac{20 \times 10 \times 15}{20 \times 15 - x(20-10)} = \frac{300}{30 - x}$$

x	0	2	4	6	8	10	12	14	15
B_x	10	10.71	11.54	12.5	13.64	15	16.67	18.75	20

Step 5: Design of Bed level at different sections

At Section 4-4,

RL of canal bed = 212 (given)

RL of water surface = 213.5 (given)

Depth of water = 1.5 m (given)

RL of Total energy line = RL of water surface + Kinetic loss

$$KL = \frac{V_4^2}{2g}$$

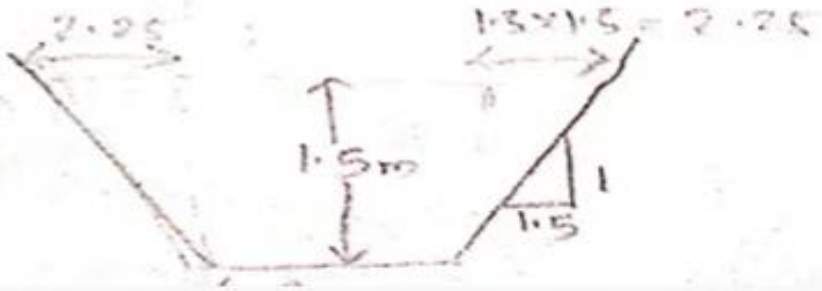
$$= \frac{(0.959)^2}{2 \times 9.81}$$

$$= 0.047 m$$

$$V_4 = \frac{Q}{A_4} = \frac{32}{33.375} = 0.959 m/$$

$$A_4 = (20 \times 1.5) + 2 \times \frac{1}{2} \times 2.25 \times 1.5$$

$$= 33.375 m^2$$



RL of TEL = 213.5 + 0.047

= 213.547 m

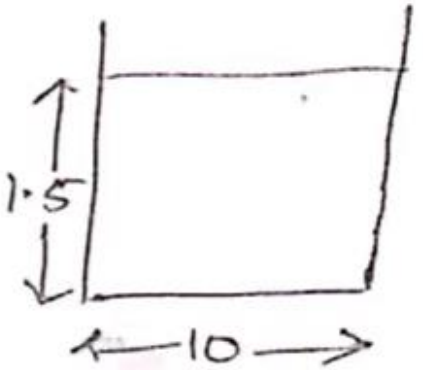
Scanned with CamScanner

At section 3-3,

RL of TEL = RL of TEL at 4-4 + Head loss (expansion loss)

$$\text{Head loss} = 0.3\left[\frac{V_3^2 - V_4^2}{2g}\right]$$

$$V_3 = \frac{Q}{A_3} = \frac{32}{10 \times 1.5} = 2.133 \text{ m/s}$$



$$H_L = 0.3\left[\frac{2.133^2 - 0.959^2}{2 \times 9.81}\right]$$

$$= 0.055 \text{ m}$$

RL of TEL = 213.547 + 0.055

= 213.602 m

RL of water surface = FSL = RL of TEL $- \frac{V_3^2}{2g}$

$= 213.602 - \frac{2.133^2}{2 \times 9.81}$

= 213.368 m

RL of canal bed = CBL = FSL − water depth

= 213.368 − 1.5

= 211.868 m

From 2-2 to 3-3, trough section is constant, the area & velocity are same at 2-2 & 3-3.

At section 2-2,

RL of TEL = RL of TEL at 3-3 + Friction loss (H_L)

$$H_L = \frac{V^2 n^2 L}{R^{4/3}}$$

$n = 0.016$

$$R = \frac{A}{P} = \frac{1.5 \times 10}{1.5 \times 2 + 10} = 1.153\ m$$

$$= \frac{2.13^2 \times 0.016^2}{1.153^{4/3}} \times 82.5 \quad = 0.079m$$

RL of TEL = 213.602 + 0.079

= 213.681 m

RL of water surface = FSL = RL of TEL $- \frac{V_2^2}{2g}$

$= 213.681 - \frac{2.13^2}{2 \times 9.81}$

= 213.45 m

RL of bed = CBL = 213.45 − 1.5 = 211.95 m

At section 1-1,

RL of TEL = RL of TEL at 2-2 + Contraction loss (C_L)

$$C_L = 0.2\left[\frac{V_2^2 - V_1^2}{2g}\right] = 0.2\left[\frac{2.13^2 - 0.959^2}{2 \times 9.81}\right] = 0.036\text{m}$$

RL of TEL = 213.681 + 0.036 = 213.716 m

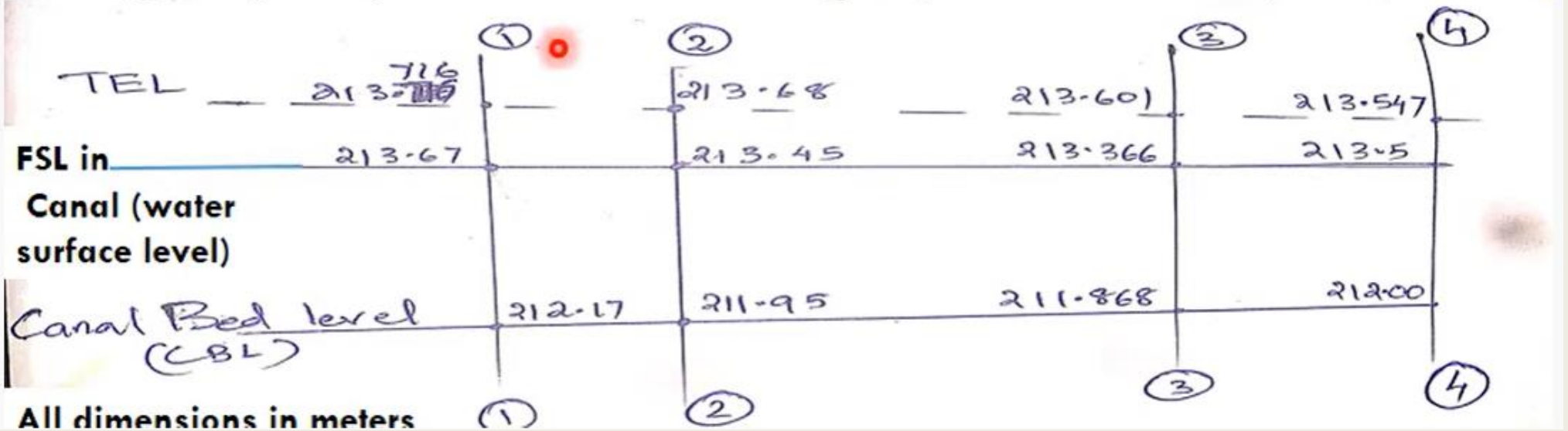
RL of water surface = $213.716 - \frac{V_1^2}{2g}$

$= 213.716 - \frac{0.959^2}{2 \times 9.81}$

$= 213.67$ m

At canal bed level, wate surface level of ... plotted.

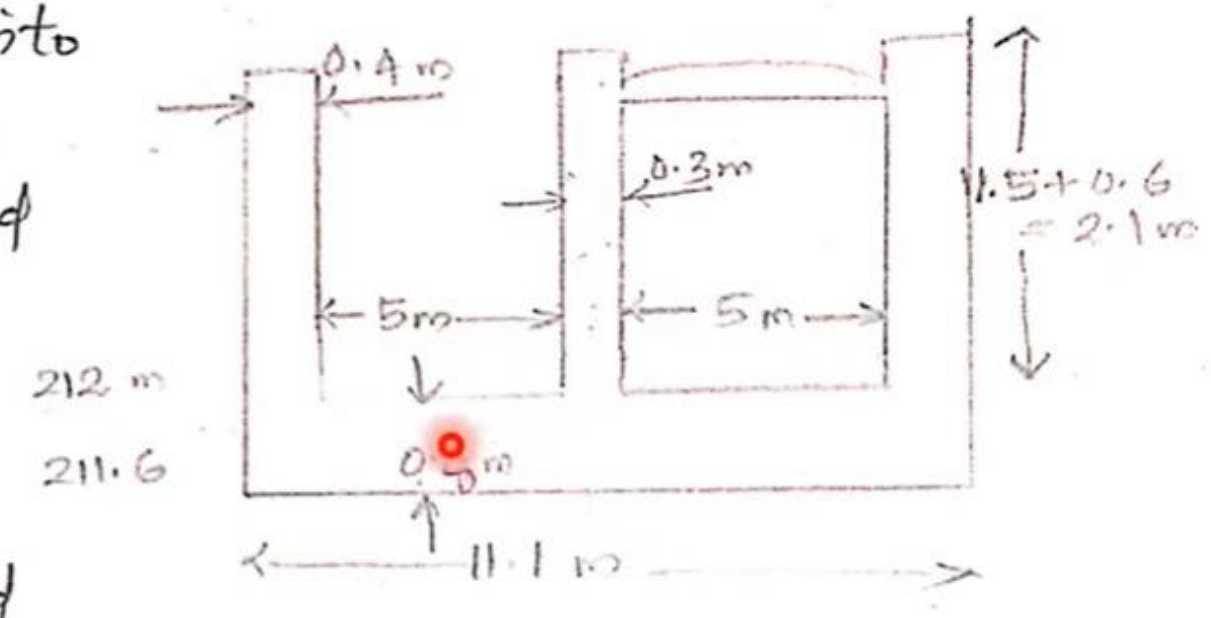
RL of bed = CBL = 213.67 − 1.5 = **212.17m**



Step 6: Design of trough

The trough is divided into two equal compartments of 5 m each & separated by an intermediate wall of 0.3 m thickness.

Bottom Slab 0.8 m thick



Inspection road is provided at the top of left compartment

A freeboard of 0.6 m provided

Ht of trough = 1.5+0.6 = 2.1 m

Thickness of bottom slab = 0.4 m

Thickness of outer walls = 0.4 m

Total width = (0.4 × 2) + 0.3 + (2 × 5)

= 11.1 m

The entire trough section is constructed as monolithic reinforced concrete.

Step 7 : Protection works

Canal wing wall - 0.5 m thick - Canal transition

Drainage wing wall - 0.8 m thick - u/s & d/s banks on drain.